

What Makes Visualizations Effective?

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External representations, notably visualizations, have been created for millennia for myriad uses: to record information, to convey information, to promote inference and creative thought. As anyone who has tried to assemble knock-down furniture knows, not all visualizations are successful.

Effective visualizations (like effective language) select and emphasize important information and eliminate irrelevant information that clutters and distracts. An aerial photograph, despite photorealism, makes a poor map. What makes a good map depends on its' use: for driving, for driving or for hiking, for conveying disease transmission or voting patterns.

While ambiguity promotes thought, conveying information (the sorts of visualizations the workshop is concerned with) demands clarity. This means the designer must be clear what information the visualization is meant to convey. It also requires knowing how people will perceive the visualization and make sense of it. Effective visualizations abide by two principles. According to the Apprehension Principle, the structure and content of the visualization must be readily and accurately perceived and comprehended. According to the Congruence Principle, the structure and content of the visualization must correspond to the desired structure and content of the mental representation to be instilled. Each of these presents challenges.

Take animation as an example. To say that there has been enormous enthusiasm for animations is an understatement. However, a review of several dozen studies that compared animated and comparable still graphics for teaching a broad range of concrete and abstract concepts did not find a single study that showed an advantage to animated graphics. Most animations violate the Apprehension Principle. They have too many moving parts; learners don't even know where to look. However, even simple animations, a single slowly moving dot, are not more effective than static graphics. Animations are fleeting whereas static graphics can be inspected and reinspected. But, even deeper, animations violate the Congruence Principle as people conceive of dynamic processes as a sequence of steps. Thus, designing effective animations is a challenge. We believe they must explain rather than merely show, using changes in perspective and scale, examples, and analogs..

We (our research group, especially Julie Heiser, plus Pat Hanrahan's research group, and Maneesh Agrawala) have developed a program for developing design principles for visualizations for specific domains. First, participants produce visualizations and these

are analyzed for their structure and their graphic devices. These are translated into design principles which undergo user testing. Finally, the design principles are instantiated into algorithms for automatic generation of visualizations. One project developed effective route maps, which consist of paths and nodes, where exact distances and angles are unimportant. A second project has developed effective assembly diagrams, which should be step-by-step action diagrams showing perspective of assembly operations, enriched by guidelines and arrows. Extending the program to develop design principles to other domains is yet another challenge.